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THIN-FILM SENSORS FOR SPACE PROPULSION TECHNOLOGY:  
FABRICATION AND PREPARATION FOR TESTING

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The goal of this work is to develop and test thin-film thermocouples for space shuttle main engine (SSME) components. Thin-film thermocouples have been developed for aircraft gas turbine engines and are in use for temperature measurement on turbine blades up to 1800 °F (refs. 1 to 3). Established aircraft engine gas turbine technology is currently being adapted to turbine engine blade materials and the environment encountered in the SSME, especially severe thermal shock from cryogenic fuel to combustion temperatures. Initial results using coupons of MAR M-246(+Hf) and PWA 1480 have been followed by fabrication of thin-film thermocouples on SSME turbine blades. Current efforts are focused on preparing for testing in the Turbine Blade Tester at the NASA Marshall Space Flight Center (MSFC). Future work will include testing of thin-film thermocouples on SSME blades of single crystal PWA 1480 at MSFC.

Successful fabrication and testing of thin-film thermocouples on a coupon of SSME high-pressure fuel turbopump (HPFTP) material (DS MAR M-246(+Hf)) was discussed previously (ref. 4). The same procedure, adapted from aircraft technology (ref. 3), was used on an HPFTP blade. The test specimen was coated with 120  $\mu\text{m}$  of NiCoCrAlY (PWA 270 Spec. - Chromalloy Corp.). An adherent, electrically insulating  $\text{Al}_2\text{O}_3$  film was then grown for 50 hr. This thermally grown film was followed by a sputtered  $\text{Al}_2\text{O}_3$  film. Finally, the thin-film thermocouple of Pt/Pt(13% Rh) was deposited. A typical fabrication process on a plasma jet sprayed NiCrAlY-coated SSME blade is shown along with that for a jet aircraft gas turbine blade in figure 1. An example of a recently fabricated device is shown in figure 2.

Currently work is underway to prepare for testing of the SSME blade in MSFC's turbine blade tester (shown schematically in fig. 3). We anticipate completing at least one round of testing during the next 5 months. The instrumented blade will be inserted into a blade holder, supplied by MSFC (fig. 4), in the middle position and will be surrounded by two other SSME blades with or without instrumentation, depending on the test requirements. The test will be conducted with the instrumented blades in a wired holder installed in the turbine blade tester at either blade position A or B. Since only the middle blade experiences close to SSME conditions, only one blade per holder assembly will model SSME conditions during a run on the turbine blade tester. A mockup is being prepared with wiring to the installed instrumentation on the blades. Final qualification at MSFC will precede final design and building of a holder to accommodate the wiring and instrumented blades.

In a related development, we have successfully instrumented coupons of single-crystal PWA 1480. It is anticipated that this material will eventually replace the current MAR M-246(+Hf). Thermal cycling data (fig. 5) show the

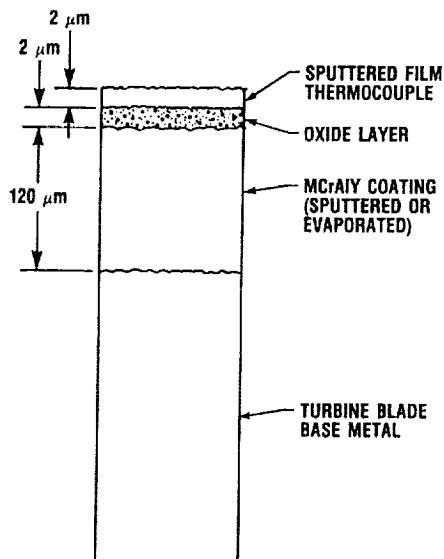
thin-film thermocouple on single-crystal PWA 1480 to be of comparable survivability with thin-film thermocouple on coupons of MAR M-246 (ref. 4). Successful application of this technology to this blade material will allow rapid response to testing needs in the future for single-crystal PWA 1480 blades. A further enhancement of our ability to respond to future testing needs is our recent improvement of our in-house capability to fabricate, test, and characterize devices. We have expanded our analytical capability (ref. 4) with an energy dispersive x-ray spectroscopy instrument (which allows elemental identification of materials).

#### REFERENCES

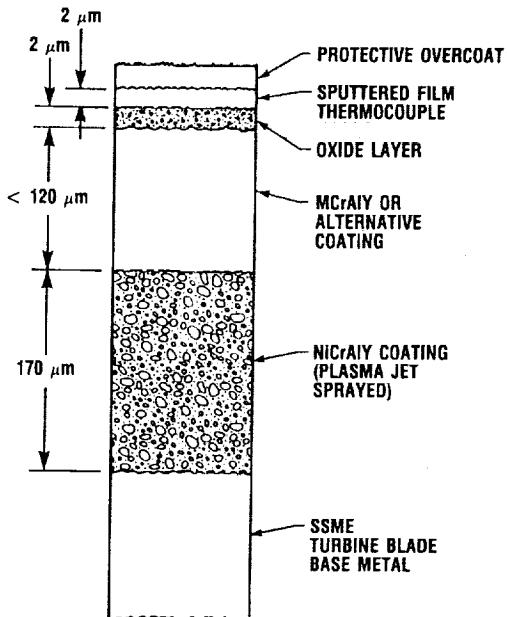
1. Dils, R.R.; and Follansbee, P.S.: Superalloy Sensor. Superalloys: Metallurgy and Manufacture, Kear, B.H.; Muzyka, D.R.; Tien, J.K.; and Wlodek, S.T., eds., (Claitor, Baton Rouge, LA, 1976) pp. 37-44.
2. Kreider, K.G.; Semanicik, S.; and Olson, C.: Advanced Thin Film Thermocouples. (National Bureau of Standards; Interagency Agreement C-54715-D, NBSIR-84-2949), NASA CR-175541, 1984.
3. Grant, H.P.; Przybyszewski, J.S.; Claing, R.G.; and Anderson, W.L.: Thin Film Temperature Sensors, Phase III. (United Technologies Corp., Pratt & Whitney Aircraft Group, NASA Contract NAS3-22002) NASA CR-165476, 1982.
4. Kim, W.S.: Progress on Thin-Film Sensors for Space Propulsion Technology. Structural Integrity and Durability of Reusable Space Propulsion Systems. NASA CP-2471, 1987, pp. 39-42.

### BASIC THIN-FILM THERMOCOUPLE TECHNOLOGY

#### JET AIRCRAFT



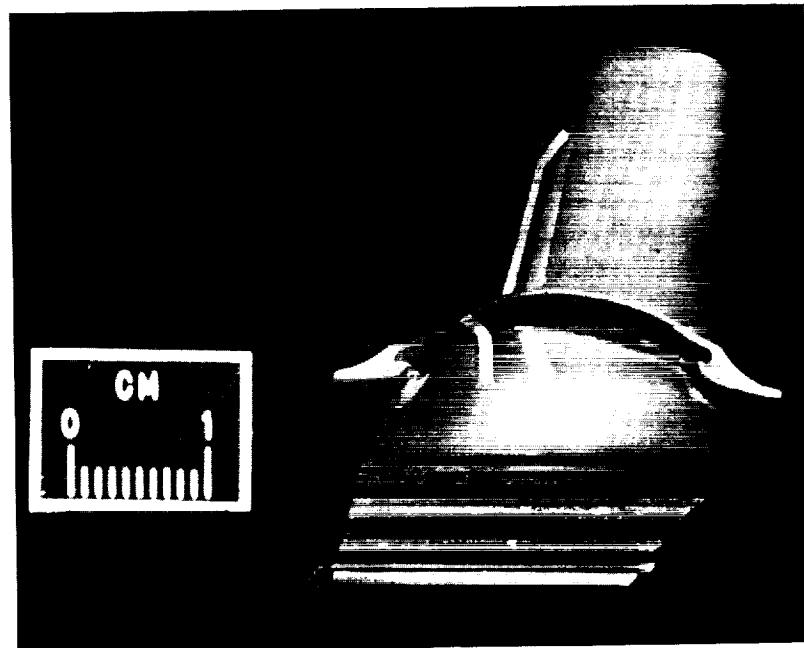
#### SPACE SHUTTLE



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Figure 1

## THIN-FILM THERMOCOUPLE ON SSME BLADE



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Figure 2

## SCHEMATIC OF MSFC TURBINE BLADE TESTER

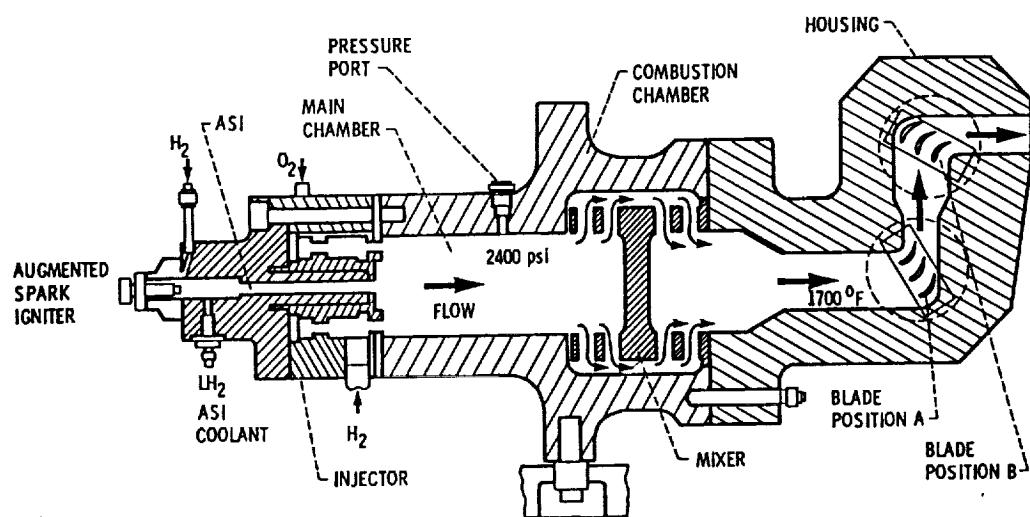
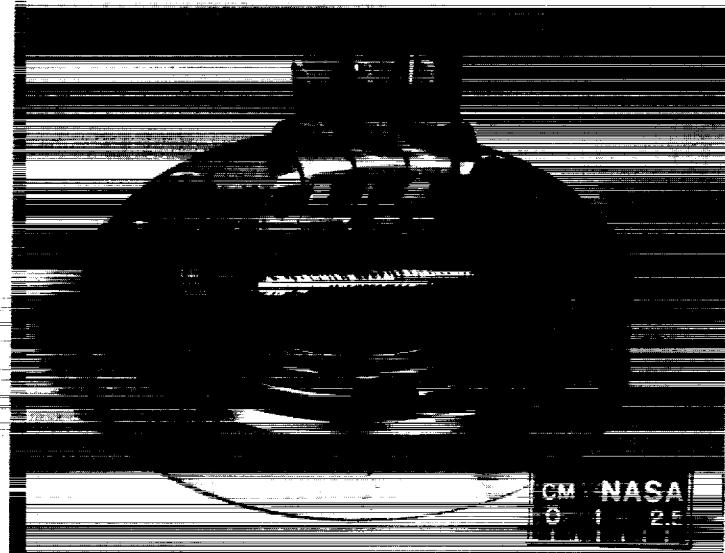
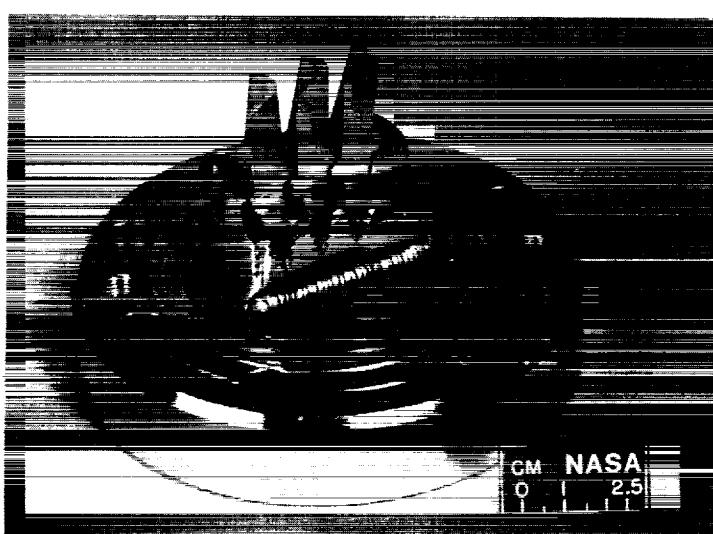


Figure 3

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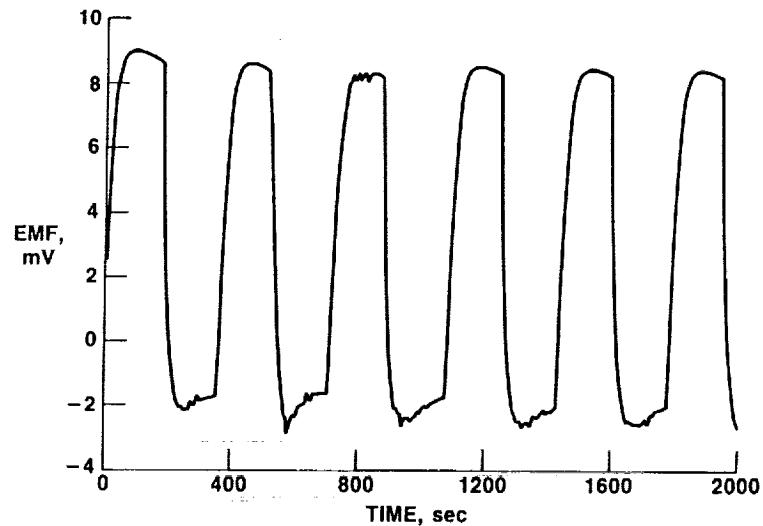
## HOLDER FOR TURBINE BLADE TESTER CONTAINING THREE SSME BLADES



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Figure 4

### SIGNAL OUTPUT OF THIN-FILM THERMOCOUPLE DURING THERMAL SHOCK CYCLING BETWEEN LIQUID NITROGEN TEMPERATURE AND 2000 °F THIN FILM THERMOCOUPLE ON SC PWA 1480



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Figure 5